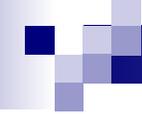


Liquid and Solid Carriers Group

Strategic Directions for
Hydrogen Delivery Workshop
May 7-8, 2003
Crystal City, Virginia

Main Themes/Caveats

- All new hydrogen carrier options must be analyzed from point of production to point of consumption basis
- There is much overlap between delivery and storage (including on-board)
 - Some technologies could function as both
 - Different targets for different uses
- Must evaluate safety and risk of any delivery system early in investigation



Main Themes/Caveats

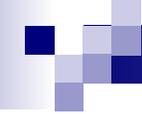
- All delivery options must be compared to conventional benchmarks (e.g., centralized, distributed)
- We should not exclude a concept because it does not quite meet the goals but has other redeeming features

Targets/Objectives

- \$1.50/kg goal is an extreme challenge
 - Does not account for fuel economy gains
 - Does not account for externalities
 - Life-cycle costs are more appropriate
 - Will only be met chiefly through reducing cost of delivery
- Targets are for on-board storage; not applicable for delivery
- Carrier-specific targets would be most useful; analysis is needed to set targets

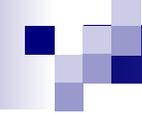
Priority Barriers

- Lack of comparative systems analysis of carrier options and alternatives
- Nanotubes offer promise but require extensive R&D
- High wt./kg H₂ for reversible hydride solids
- Decomposition temperature to H₂ is too high for existing reversible liquid carriers
- Uncertainty regarding which Fischer-Tropsch liquids make the best H₂ carriers
- Safety in vehicle accidents is key consideration



R&D Needs

- Analysis
- Reversible Liquid Carriers
- Irreversible, Non-Regenerable Carriers
- Reversible Hydrides
- Irreversible Regeneration
- Computational and Analytical Tools
- Nanotubes and Other Carbon Structures



R&D Priorities

- Benchmarking comparison analysis (point of production to point of consumption) of delivery methods and impact on overall systems integration
- Identify, discover, and utilize the optimum reversible liquid hydrogen carriers
- Fundamental R&D on carbon nanostructures for storing hydrogen

R&D Priorities (2)

- Increase the wt. % of metal hydrides and possible optimize for slurry delivery
- Computational and analytical tools to evaluate hydrogen carriers (storage capacity and reaction heats)
- Low-cost, efficient, irreversible hydride regeneration coupled with hydrogen manufacture

“Take home” messages

- We operate in market-driven economy; our targets must recognize this fact
- We should not exclude a concept because it does not quite meet a goal but has other redeeming features
- All new hydrogen carrier options must be analyzed on a point of production to point of consumption basis.

“Take home” messages (2)

- There is much overlap between delivery and storage (including on-board)
- Must evaluate safety and risk of any delivery system early in investigation
- Analysis is critical near-term need; go/no go decisions will be needed
- Thermodynamics will drive long-term costs
- Gas and energy industries are key partners (with universities, national labs, etc.) in all R&D efforts